The Biological Condition of Cox's Creek and Cox's Rivulet: November 2004.

Report to Dorset Council

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1. Introduction

The condition of Cox's Creek and Cox's Rivulet downstream of the Scottsdale WWTP discharge was assessed by Davies and Cook (2002) conducting a biological survey of aquatic macroinvertebrates in early November 2002. That survey was designed to provide a picture of the condition of the receiving streams for the Scottsdale WWTP discharges in comparison with state-wide standards derived from a large database of minimally polluted reference sites. Four other local reference stream sites were also sampled for comparison, in Hurst Creek and Tuckers Rivulet. The survey indicated that the upper reaches of Cox's Creek and Rivulet downstream of the WWTP discharge were in very poor condition, with severely depleted macroinvertebrate assemblages dominated by forms tolerant of organic pollution (e.g. worms, chironomid midges).

The survey was repeated in November 2004, following substantial change to the nature of the Scottsdale WWTP discharge after the closure of the Simplot factory, whose wastewater was discharged via the WWTP.

As in the 2002 survey, macroinvertebrate samples were collected using a standard kick sampling technique. However, fish populations were sampled at several sites for the first time in 2004.

2. Methods

2.1 Sampling sites

Site locations are shown in Figure 1 and details are shown in Table 1. 10 sites were sampled in November 2004, with 5 sites sampled between 250 m downstream of the Cox's Creek WWTP discharge in Cox's Creek to 13.4 km downstream of the discharge, in Cox's Rivulet. In addition, one site was sampled in the headwaters of Cox's Rivulet, and in the upper and lower reaches of the neighbouring catchments of Hurst Creek and Tuckers Rivulet. These latter sites were sampled to ascertain the condition of other local streams which were not experiencing impacts from WWTP wastewaters. These streams are however, at least partially impacted by agricultural landuse, including dairy farming, and impacts of farm dams on flows and water quality. The two downstream sites on Cox's Rivulet and Hurst Creek had been channelised.

Table 1. Stream sites sampled for macroinvertebrates in November 2004 (grid references use the AGD 1966 datum).

Site name	Site Code	Easting	Northing	Catchment area km^2	Distance from WWTP, km
Cox's Rivulet at Burnside Rd.	CRUS	542525	5446000	2.4	
Cox's Creek downstream of WWTP discharge	CCDS	542975	5445350	0.67	0.25
Cox's Creek at Burnside Rd.	CCB	543300	5446600	2.6	1.75
Cox's Rivulet at Brockett's Rd.	CRBR	542425	5447850	7.3	3.4
Cox's Rivulet at Maslin's Rd.	CRMR	541300	5452013	21.5	7.9
Cox's Rivulet at Boddington's Rd.	CRBOR	538025	5456350	33.6	13.4
Tucker's Creek at North Scottsdale Rd.	TNS	544400	5444150	6.3	
Tucker's Creek at Barnbougle Rd.	TBR	544050	5458625	18.7	
Hurst Creek at Oak Dene Rd.	HOR	538800	5446450	9.1	
Hurst Creek at Boddington's Rd.	HBR	536725	5455975	44.8	

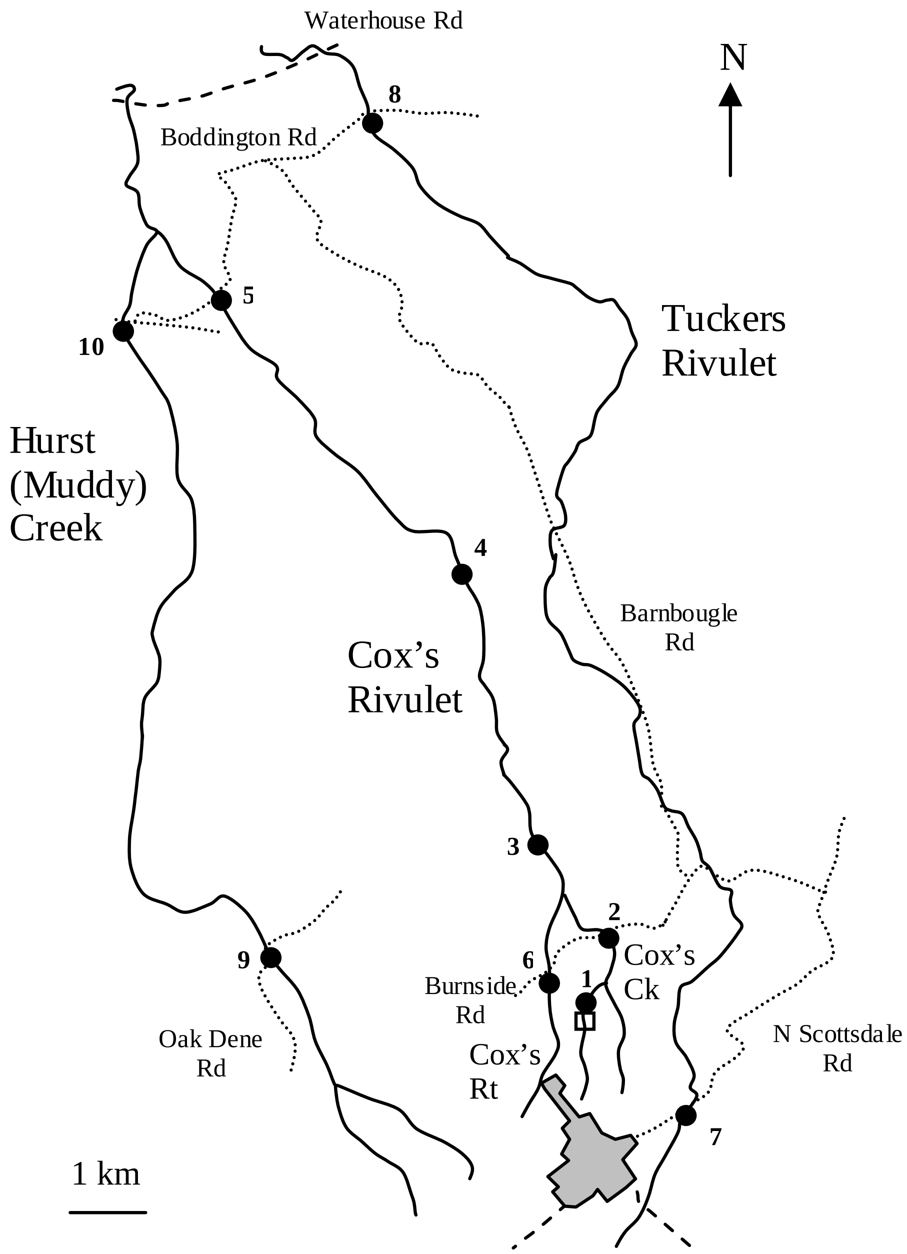


Figure 1. Map of stream sites in the vicinity of Scottsdale sampled for macroinvertebrates in November 2004. Roads are indicated by dashed lines, and the WWTP discharge location on Cox's Ck is indicated by a square. Sample sites are shown as filled circles and numerals as follows: 1 CCDS, 2 CCB, 3 CRBR, 4 CRMR, 5 CRBOR, 6 CRUS, 7 TNS, 8 TBR, 9 HOR, 10 HBR. The grey shape indicates Scottsdale.

2.2 Sampling methods

At each site two replicate samples were taken of macroinvertebrates by the standard AUSRIVAS sampling protocol - disturbing a 10 m length of stream bed in 'riffle' habitat by foot immediately upstream of a standard kick net (with 250 micron mesh). The material captured in the net was then sorted by hand on-site in a white tray, for 30 minutes, maximising the number of taxa collected while also collecting families in proportion to their occurrence in the sample. All macroinvertebrates were preserved in 90% ethanol-glycerol prior to being identified and counted in the laboratory. Identification was to family level (for all taxa except Acarina, Oligochaetae, Copepoda, Turbellaria, Nematoda, Hirudinea, Collembola and Chironomidae, the latter being identified to sub-family level). All data was entered into Excel spreadsheets prior to checking and data analysis.

Fish were sampled quantitatively at six sites by electrofishing – sites CRBR, CRMR, CRBOR, TBR, HOR, and HBR - using a Smith-Root backpack unit operated with a two person team. 100m of the stream was fished, in three separate passes, with all habitats actively searched. All fish were counted, identified and measured (fork length to nearest mm).

A suite of environmental variables was also collected at each site, including details of channel dimensions, riparian vegetation cover, stream substrate composition, surface cover of silt, organic debris, moss and algae, and conductivity. A number of site variables were also determined from maps, including distance from source and the WWTP discharge point, catchment area, stream slope, elevation and stream order.

2.3 Data analysis

Several forms of data analysis were conducted.

Univariate analysis

Total abundance and taxon richness (number of families) were derived from the each sample. Plots of these variables and of the abundance of individual taxa against distance downstream of the WWTP discharge were prepared. Differences in these variables derived for sites in Cox's Creek and Cox's Rivulet and their value in control streams were also examined and compared by t-test (using a one-tailed test and assuming equal variances). Three control sites were used for comparison – TNS, TBR and HOR. These sites were partially affected by agricultural development in their catchments, and thus acted as controls for the assessment of WWTP discharge over and above any background impacts from land clearing etc.

Differences between results from the 2002 and 2004 surveys were assessed graphically, and by paired t-test (sites paired by year).

AUSRIVAS analysis

AUSRIVAS (the Australian River Assessment Scheme) allows a stream's macroinvertebrate fauna to be compared statistically with the fauna expected to occur at a sample site ('test site') if pollution or other human impacts were absent. An 'expected' macroinvertebrate fauna is predicted from a statistical model developed from a large database of reference sites collected from all major catchments in the state. The system produces a score for the site, called the O/E ("O over E") score, which is the proportion of macroinvertebrate families expected (E) to occur at the site that are actually found (observed or O) there. O/E scores range from 0 (with none of the expected families observed, and hence highly impacted) to around 1 (with all of the expected families observed, and hence being in a relatively unimpacted or "equivalent to reference" condition). This score range is divided into bands, with values around 1 being rated as 'A' or unimpaired ('equivalent to reference'), while values falling below the A band are rated as either B (significantly impaired), C (severely impaired) or D (extremely impaired). This allows the degree of impairment derived from the O/E score to be described in a standard way. The widths of the bands are derived from the spread of O/E values determined for reference sites, and hence test sites with O/E values falling below A are significantly impaired in both a statistical and ecological sense. AUSRIVAS predictive 'models' have been developed for all states and territories in Australia (under the National River Health Program, see ausrivas.canberra.edu.au), and there are models developed for Tasmanian streams. All sites assessed in this report were sampled and analysed using the AUSRIVAS sampling protocol for Tasmania, and the models developed for the spring sampling season.

All macroinvertebrate data was entered into the appropriate Tasmanian AUSRIVAS model for the spring season and riffle habitat, along with the environmental variables required for making the prediction of the expected taxa and calculating the O/E score. Two AUSRIVAS models were used, one based on presence/absence data alone (the ‘PA’ model) and one based on rank (or relative) abundance (the ‘RK’ model). The PA model provides O/E scores (OEpa) which measure deviation from reference condition based on loss of families, while the RK model derived O/E values (OErk) whose deviation from reference is based on loss of families as well as changes in relative abundance in the remaining taxa. Differences between OEpa and OErk are frequently useful in interpreting the nature of the impacts detected.

3. Results

3.1 Biological and Environmental Characteristics and Trends

As in 2002, all sites in the survey were of moderate to low gradient and, apart from TBR, had highly sandy stream beds, and were dominated by run habitats with few riffles. The riparian vegetation was generally in poor condition with only sites CRBR, CRMR and HOR having near-natural riparian vegetation. The surrounding and upstream lands for most sites were mostly cleared for pasture/cropping, with the exception of CRMR and parts of Tuckers Rivulet. Sites upstream of CRBR on Cox's Rivulet and Cox's Creek have essentially been completely cleared of native riparian and catchment vegetation., and the upper sections of the catchments of Tuckers Rivulet and Hurst Creek are extensively cleared, and have little intact native riparian vegetation and chains of instream farm dams.

Background (control stream) conductivities at the time of sampling (at baseflow) were in the 80 - 160 EC unit (microS/cm) range, with a mean of 134 EC. Values recorded for sites CRUS, TNS, TBR, HOR, HBR were 82.3, 113.3, 150.7, 160.7 and 163.2 EC respectively. Conductivity in Cox's Creek downstream of the WWTP discharge (site CCDS) was substantially higher (453 EC on 23 November 2004), declining with distance downstream to 192 EC in Cox's Rt at Boddington Road (CRBOR).

The overall composition of the fauna of the sample sites is shown in Table 2. The macroinvertebrate fauna of the control streams was quite variable, as in 2002. Stream sites in better environmental condition (eg HOR, TBR) contained mayflies (ephemeroptera), and a variety of caddis (Trichopteran) and true fly (Dipteran) families. Sites downstream of the WWTP (CCDS, CCB) had high proportions of worms (oligochaetae) and chironomiin midges in their fauna. This is consistent with nutrient and/or organic enrichment, and siltation. Site CRUS, in the uppermost reach of Cox's Rivulet had moderate diversity and condition, though both were higher than in 2002, probably due to higher flows preceding sampling.

Table 2. Macroinvertebrate community composition of sites sampled in Cox's Ck and Rivulet, Hurst Creek and Tuckers Rivulet in November 2004. Abundance as recorded in each live-pick sample. Total number of taxa and abundance also shown, along with O/E values (estimated using both RK and PA models, and impairment band). Note severe impairment at sites downstream of WWTP, with recovery downstream.

			Code:	**CRUS**		**CCDS**		**CCB**		**CRBR**		**CRMR**		**CRBOR**		**TNS**		**TBR**		**HOR**		**HBR**	
			River:	Cox's Rt		Cox's Ck		Cox's Ck		Cox's Rt		Cox's Rt		Cox's Rt		Tucker's Ck		Tucker's Ck		Hurst Ck		Hurst Ck	
			Site:	Burnside Rd		D/S discharge		Burnside Rd		Brockett's Rd		Maslin's Rd		Boddington Rd		Nth Scottsdale Rd		Barnbougle Rd		Oakdene Rd		Boddington Rd	
			Sample:	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Class	**Order**	**Family**	**Sub family**																				
	Turbellaria							1	1														
																	1						
Mollusca	Bivalvia	Sphaeriidae			4										10		5	2			2		1
	Gastropoda	Hydrobiidae		23	18				1							1	1						
		Planorbidae						18	33	7	4					2	1						
Annelida	Hirudinea								1							4	1						
	Oligochaeta			2	2	23	29	66	700	7	9	5		8	3	9	20	3	1	3	7		1
Arachnida	Acarina			1						2	2					4		4	4	2		2	1
Crustacea	Amphipoda	Paramelitidae										1	2		1					10	7		1
		Corophiidae												93	113								
		Paracalliopidae													1							1	1
	Copepoda										1												
	Isopoda	Phreatoicidea																			3		
	Ostracoda				2			7	23		10					7	15						
Decapoda		Hymenosomatidae			1															1	1		
Insecta	Plecoptera	Gripopterygidae			1								2		10			2	2			45	30
		Notonemouridae		4	19	2	1		2	17	3												
	Ephemeroptera	Leptophlebiidae			2							22	23	2	8			6	8	20	20	20	26
		Oniscigastridae																		17	35		
		Baetidae			1													2					1
	Odonata	Synthemidae			1										1								
		Telephlebiidae																3					
	Hemiptera	Veliidae		1	7				1	5								2	2				
		Corixidae		1															1				1
	Mecoptera	Nannochoristidae		1	10							1		1				1	1	15	10	2	2
	Diptera	Chironomidae:	Chironominae	16	6	55	35	59	77	26	29	2	5			40	60	6	6	3	7	2	
		Chironomidae:	Orthocladiinae	19	19		10	22	4	32	9		2	5	6			54	6	7		4	21
		Chironomidae:	Tanypodinae		1			5	3	2	3	1	1	1	2	10	2	2	6	3	5		2
		Simuliidae			1					97	41	3	7					14	22		1	2	2
		Tipulidae		1	3	1				1		16	3		1			1	2	8	8		2
		Athericidae											1							1	1		
		Ceratopogonidae		1	1						1					2		1			1		1
		Dixidae			7																		
		Empididae			1					1								1	1				
		Muscidae					5																
		Psychodidae			1																		
		Stratiomyidae			1																		
		Syrphidae					1																
		Tanyderidae																		2	1		
		Dip. Unid. Pup.				4	3	2	2	1						5	4						
	Trichoptera	Atriplectididae												5	1				5	1	2		2
		Calocidae										2	3		1								
		Conoesucidae												1	10			52	16				1
		Helicophidae										9	4										
		Hydrobiosidae		3	24					6		4	1		2			27	6			3	3
		Hydropsychidae										4	2					65	7				
		Hydroptilidae																				2	7
		Leptoceridae								3	58	2	1	3	10			4	50	2	5	13	22
		Philorheithridae										3											1
	Coleoptera	ElmidaeA										5	5	1	4		1	18	10	1			
		DytiscidaeA																					1
		HydrophilidaeA					1																
		ElmidaeL		1											2			7					
		ScirtidaeL		2	1		1												1	1			
		DytiscidaeL					2				1												
		HydrophilidaeL			1																		
			N taxa	**14**	**25**	**5**	**10**	**8**	**12**	**14**	**13**	**15**	**15**	**10**	**18**	**10**	**11**	**22**	**20**	**17**	**17**	**11**	**22**
			Total abundance	**76**	**135**	**85**	**88**	**180**	**848**	**207**	**171**	**80**	**62**	**120**	**186**	**84**	**111**	**277**	**157**	**97**	**116**	**96**	**130**
			O/Erk	**0.5099**	**0.7845**	**0.169**	**0.212**	**0.252**	**0.294**	**0.569**	**0.406**	**0.587**	**0.713**	**NA**	**0.7931**	**0.27822**	**0.23847**	**0.9295**	**0.6584**	**0.528**	**0.4062**	**0.5008**	**0.8763**
			Band (rk)	**B**	**B**	**C**	**C**	**C**	**C**	**B**	**B**	**B**	**B**	**NA**	**A**	**C**	**C**	**A**	**B**	**B**	**B**	**B**	**A**
			O/Epa	**0.4966**	**0.7725**	**0.176**	**0.176**	**0.234**	**0.409**	**0.563**	**0.45**	**0.701**	**0.818**	**NA**	**0.6975**	**0.33483**	**0.27903**	**0.98**	**0.7622**	**0.5631**	**0.5068**	**0.523**	**0.9298**

The trend in abundance and diversity observed in the stream reaches downstream of the WWTP discharge is shown in Figures 2 and 3. Diversity was low immediately downstream of the discharge point, but increased rapidly with downstream in Cox's Creek. The influence of Cox's Creek on Cox's Rivulet was not marked, as it was in 2002. Diversity reached levels similar to that observed in the unpolluted streams by just below the Cox's Rt and Cox's Creek junction (site CRBR), 3.4 km downstream of the discharge point.

Total abundance is very low immediately downstream of the discharge, probably due to the toxic nature of the discharge (with elevated ammonia and carbon dioxide levels). It increases rapidly in the lower reaches of Cox's Creek, by site CCB. Worms and midge larvae – both groups highly characteristic of a stream response to high organic loading – are dominant in Cox's Creek. The relative dominance by these two groups declines downstream, presumably in response to decreased organic loadings (reduced by the biological activity of microbes and macroinvertebrates on the stream bed). Oligochaetes decline rapidly to < 5% relative abundance in Cox's Rt downstream of the junction with Cox's Creek, while chironomids decline more gradually with distance downstream in Cox's Rt.

Taxa more typical of clean water streams – caddis and mayflies - increase in abundance at sites CRMR and CRBOR. Leptophlebiid mayflies, indicators of good water quality and typical of unpolluted sites, increase to 32% relative abundance at site CRMR.

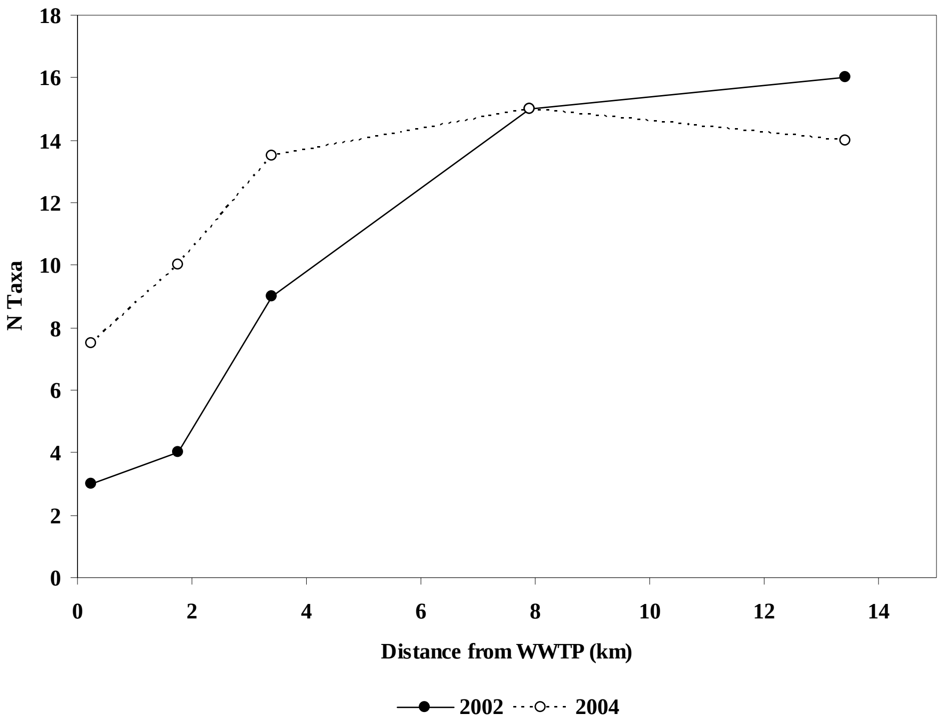
The pattern in Cox's Creek is typical of a stream system which receives a high organic loading, leading to high biomass of worms and chironomids (both sediment and detrital bottom feeders). Some 13 km downstream, the stream has largely returned to an unpolluted state. The stream is continuing to provide a degree of secondary treatment of the WWTP discharge.

The trend in O/E scores downstream of the WWTP is marked, with low scores in Cox's Creek increasing downstream, and falling within the range of other local unpolluted sites in its lower reaches. O/Epa values at CCDS and CCB, indicating a loss of 70 to 82% of the expected taxa in Cox's Creek. Even as far downstream as

CRMR and CRBOR (8 - 13 km downstream), the O/Epa value still indicates a loss of 24 - 30% of expected taxa. This still represents a substantial impact on stream condition. However, these O/E values are falling in the range for the better condition reference sites, implying that the degree of impact observed in lower Cox's Rivulet is similar to that experienced at other sites in the area that are not polluted with wastewater. Cox's Rivulet upstream of Cox's Creek (CRUS) also had low O/E values, and a faunal composition consistent with diffuse impacts – most probably from catchment clearing, and not organic pollution.

Fish were present at all sites in Cox's Rivulet (Table 3), with both diversity and total abundance declining with distance upstream from the coast, a pattern observed in most Tasmanian coastal streams (Davies 1989). The species observed and the diversity were comparable to those in reference sites in comparable reaches. Thus, diversity and abundance at the middle catchment Cox's Rt site CRBR was comparable to that observed in the middle catchment reference site HOR, though with a higher density of eels (*Anguilla australis*). Diversity, abundance and the species complement present at lower catchment sites CRBOR and HBR were also not substantially different, though site TBR appears depauperate in comparison.

There was therefore no indication of a major impact on the fish assemblage of middle and lower Cox's Rt from the Scottsdale WWTP, when compared to neighbouring reference stream sites. Field observations also failed to detect any obvious lesions or signs of disease in the fish captured.



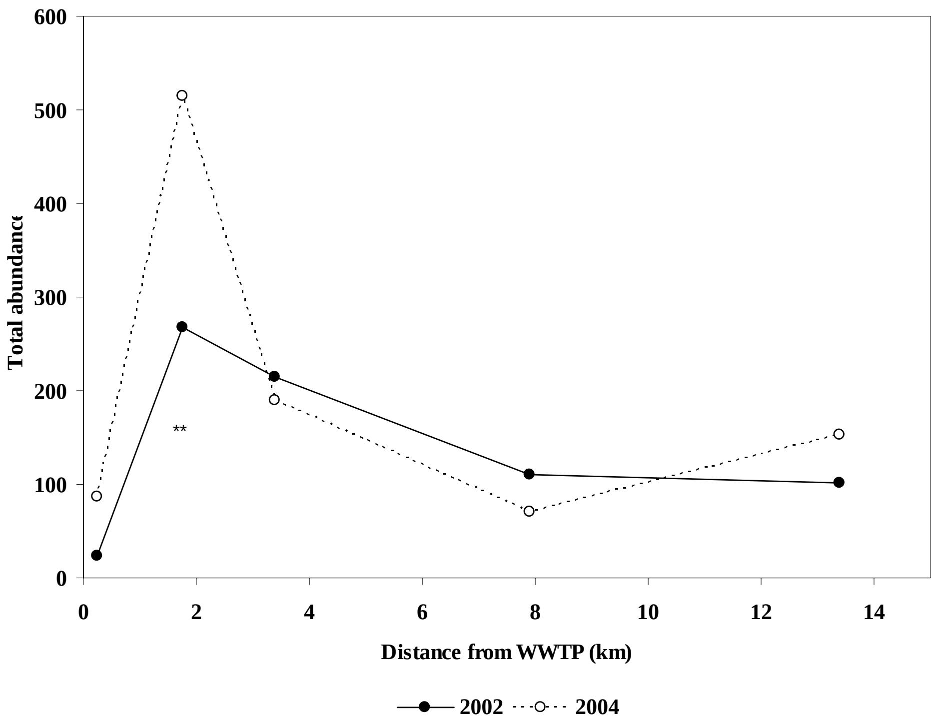


Figure 2. Plots of total macroinvertebrate diversity (number of taxa) and abundance in Cox's Ck and Cox's Rivulet, observed in November 2002 and 2004, with distance downstream from the Scottsdale WWTP discharge.

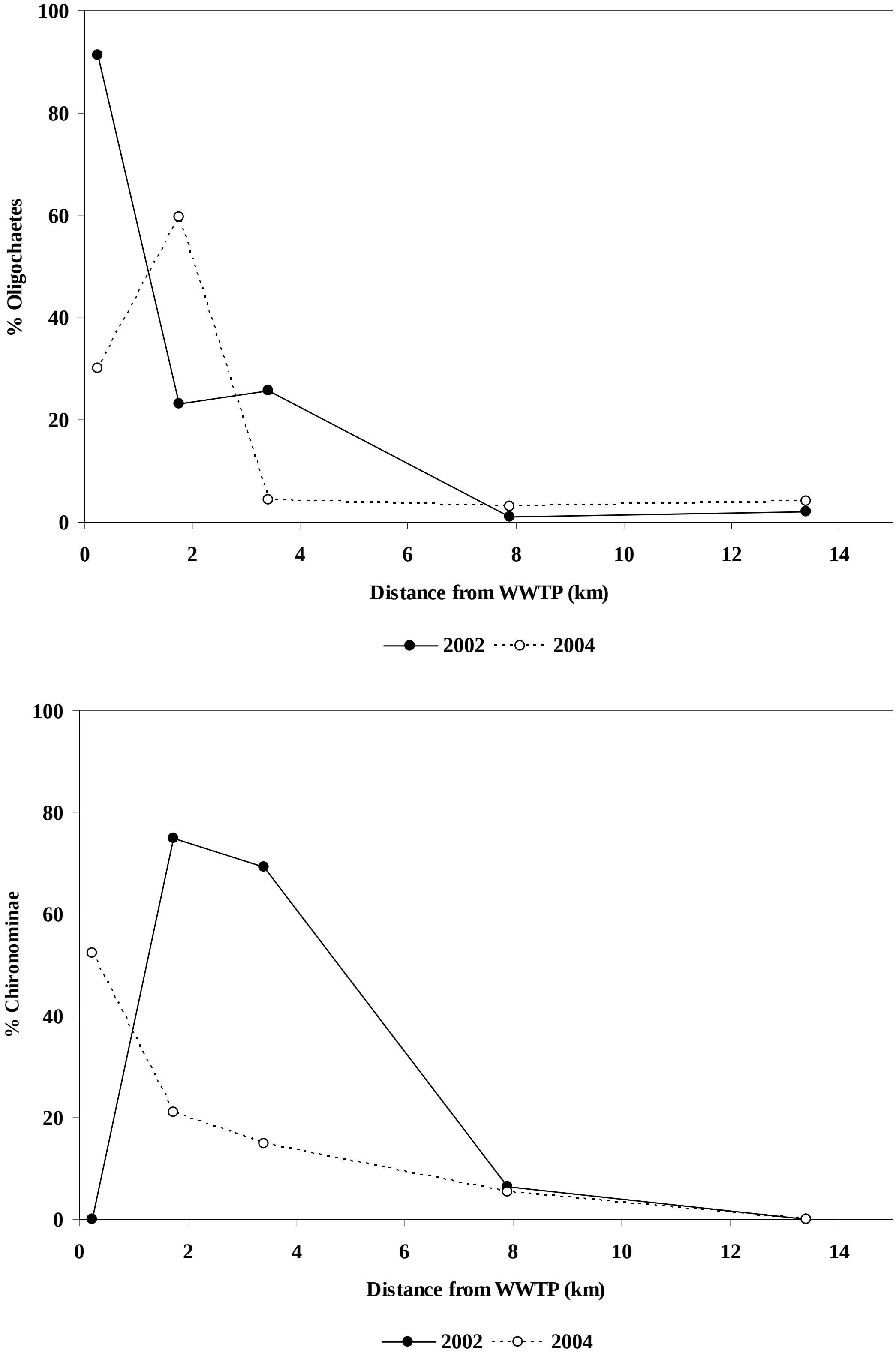


Figure 3. Plot of % abundance of worms and chironomiin midges against distance downstream of WWTP discharge in Cox's Ck and Rivulet as observed in November 2002 and 2004. Note major peaks in worm and midge abundance downstream in 2002 substantially reduced in 2004.

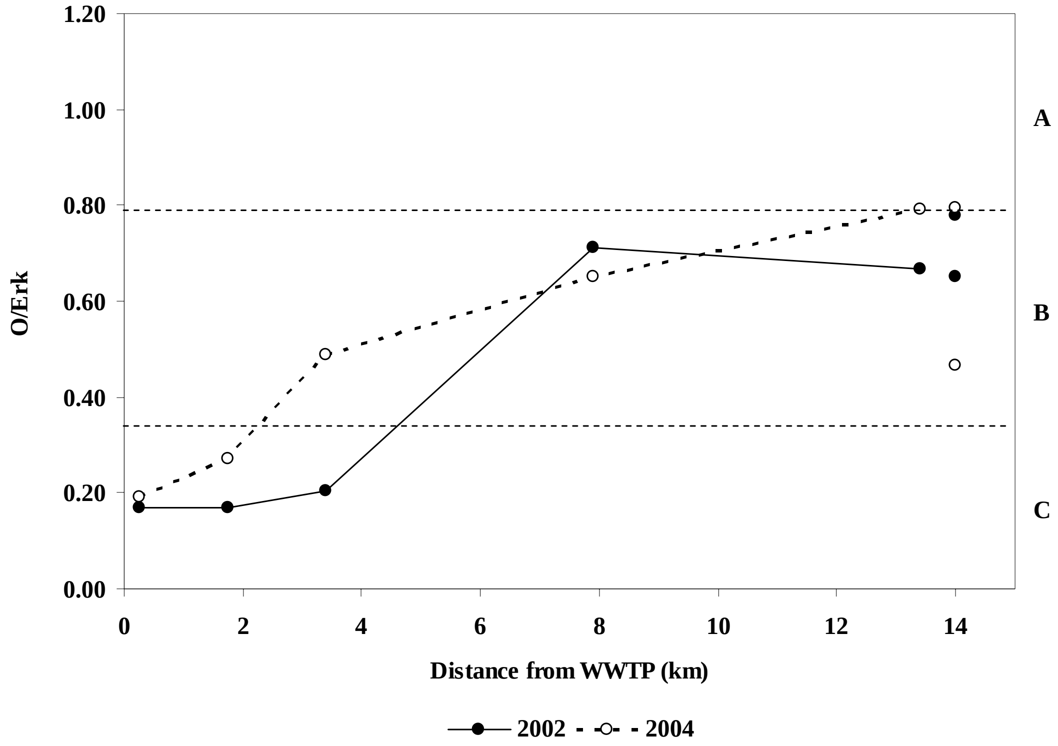


Figure 4. O/Erk values for sites in Cox's Ck and Rivulet downstream of the WWTP discharge, November 2002 and 2004. Points at right are for two control sites, TBR and HOR. Dashed lines indicate bounds between impairment bands A (equivalent to reference), B (significantly impaired), and C (severely impaired). Note substantial improvement in condition in 2004 within 2 to 6 km downstream of WWTP.

Table 3. Abundance of fish at three sites in Cox's Rivulet and at three reference sites. N captured per 100 m in a three pass fishing operation.

Species	CRBR	CRMR	CRBOR	TBR	HOR	HBR
Native fish						
Anguilla australis	31	2	12	2		11
Nannoperca australis	5		7			
Galaxias brevipinnis		3				
Galaxias truttaceus		5	21		2	93
Galaxias maculatus			11			15
Lamprey ammocoete			34			
Pseudaphritis urvillii			32	1		40
Gadopsis marmoratus				2		
Crayfish						
Astacopsis gouldi		1				
Exotic						
Salmo trutta				1	1	

3.2 Univariate analysis

One way analysis of variance (t-test) was used to assess the significance of differences in number of taxa and abundance of macroinvertebrates at sites downstream of the WWTP from control sites. Only two of the five sites of the sites sampled as reference sites controls could actually be used as such - TBR and HBR i.e. these were the least impacted of the original reference sites.

Total macroinvertebrate abundance, number of taxa and O/E scores at the site immediately downstream of the WWTP (CCDS) were all significantly lower than at reference sites ($p < 0.0001$), while abundance at sites CCB and CRBR was significantly higher ($p < 0.01$), largely due to elevated abundances of midges ($p < 0.005$). O/E scores and number of taxa were again significantly lower at these sites than at reference sites (all $p < 0.05$). The two most downstream sites (CRMR and CRMOR) were not significantly different from reference sites in abundance, number of taxa or O/E scores (all $p > 0.3$).

Neither the reference sites nor the two downstream Cox's Rivulet sites fell well inside the A or unimpacted band. Comparison of the O/E scores of these sites with O/Epa scores from all state-wide AUSRIVAS reference sites by t-test revealed that the three sites downstream of the WWTP (CCDS, CCB and CRBR) had significantly lower O/E's than reference sites ($t = 2.31$, $df = 8$, $p = 0.004$). Thus these sites all have a significantly lower O/E scores than true reference sites.

OE values for site CCDS in 2002 and 2004 were ether identical (for O/Epa) or very similar (for O/Erk). However, O/E values for the two sites further downstream were substantially higher in 2004 than in 2002 indicating a significant recovery in stream condition. Values further downstream were essentially similar in both years.

4. Discussion and Conclusions

The WWTP discharge into Cox's Creek continues to have a localised negative impact on stream condition. This is unsurprising, as wastewater constitutes the majority of stream flow in Cox's Creek for much of the time. The impact is detected throughout Cox's Creek and is detected up to 4 - 8 km downstream in Cox's Rt. Little impact is detected by 13 km downstream, however, and the biological condition of the lower reaches of Cox's Rt is similar to that experienced by other streams exposed to landuse and agricultural activity typical of the area.

The condition of Cox's Creek downstream of the WWTP discharge, as well as of the middle reaches of Cox's Rivulet (downstream of the Cox's Ck junction) has improved significantly in ecological condition since 2002. It would appear that a significant change in WWTP quality has occurred leading to a significant localised, though not complete, recovery in ecological condition.

There has been little change further downstream in Cox's Rivulet since 2002 where other factors appear to be controlling the stream's condition, which is comparable to other unpolluted streams in the area.

The Cox's Creek-Cox's Rivulet stream system follows a classic response to wastewater pollution typified by:

- a localised decline in diversity;
- an initial reduction in abundance, probably due to a localised toxic impact for around 1 – 1.5 km downstream of the WWTP discharge point;
- an increase in abundance of midge larvae and worms in a zone between around 1.5 and 3-4 km downstream;
- re-colonisation with 'clean water' taxa – mayflies and caddis – commencing at around 7 km downstream, approaching typical regional levels by 13 km downstream.

Overall the Cox's Rivulet system is still locally impacted by the discharge, with significant, though only partial, recovery in condition since 2002 between 2 and 8 km downstream of the point of WWTP discharge. The extent of the impact does not appear to extend to any significant degree beyond 8 km downstream.

The O/Epa values for the three sites sampled downstream of the WWTP are still low by state-wide standards. Figure 5 illustrates the overall, state-wide distribution of O/Epa values from Tasmanian river test sites assessed during the Australia-wide assessment of river health between 1994 and 1999, conducted by DPIWE (see Krasnicki et al. 2001).

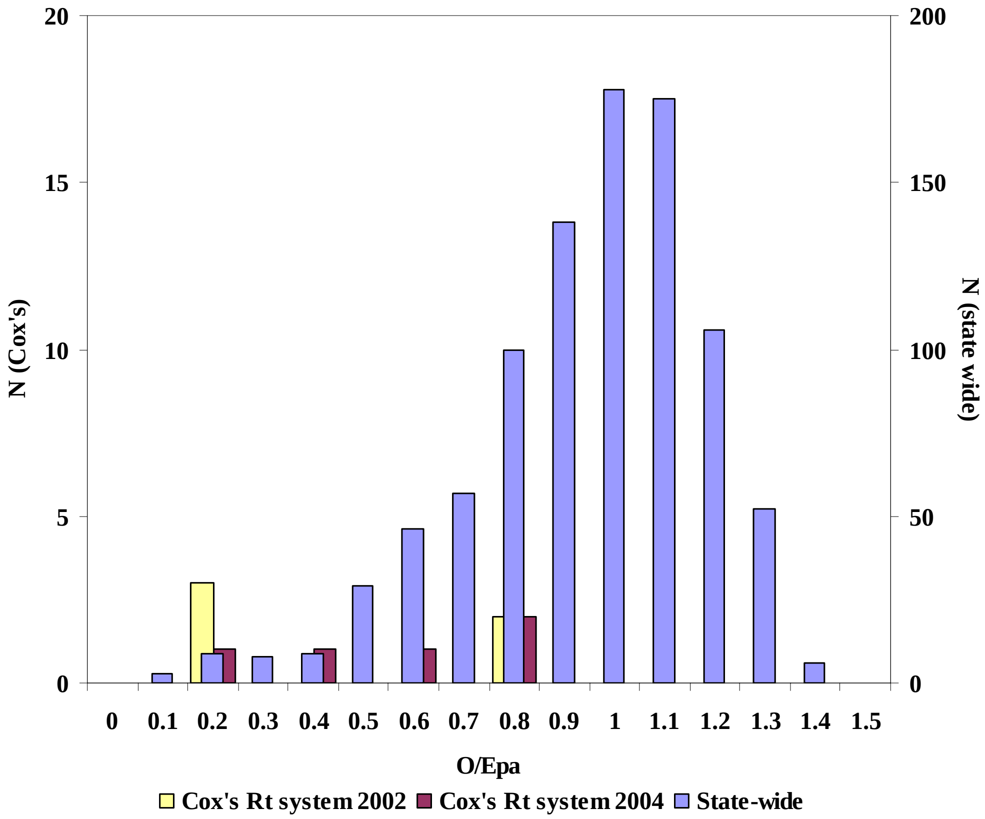


Figure 5. Distribution of all 916 O/Epa values measured at test sites across Tasmania (all sites assessed in spring at riffles, 1994 to 1999) by DPIWE, compared with values for Cox's Rivulet system downstream of the Scottsdale WWTP in 2002 and 2004. Note that the three values for sites up to 3-4 km downstream fell to the extreme end of the state-wide distribution in 2002, and that two of those sites have increased in value in 2004.

In 2002, the O/E values for the sites in Cox's Creek and in Cox's Rivulet fell in the lower 1.3% of all sites sampled across the state, while the two most downstream sites fall in the lowest 18%. The only other locations with such low values were Silver Lead Creek and the Argent River (on the West Coast), and Storeys and Aberfoyle

Creeks (South Esk catchment), all streams heavily polluted by active or historical mine workings. In 2004, two of the sites had improved substantially (Figure 5).

Fish assemblages in the middle and lower reaches of the Cox's Rivulet system contained a diversity and abundance and species complement of native fish typical of the area and comparable to those found in neighbouring, unpolluted streams. There was no evidence that the WWTP discharge causes substantial declines in native fish populations or health.

Both the 2002 and this 2004 surveys, in an attempt to collect data on other nearby catchments as references/controls for assessing the WWTP impact, also detected significant impacts on instream ecological condition in reaches of Hurst and Tuckers Rivulet. None of the reference stream sites could be classified as being in an unimpacted state, indicating that there are significant background impacts from land clearing and related agricultural activities on these streams. The WWTP discharge impact in the Cox's Rt system is super-imposed on these impacts.

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